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# ENABLING PRECONDITIONS FOR GEOMETRICAL APPLICATION IN PRECONCEPTUAL STAGES OF ENGINEERING DESIGN

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## 1 Introduction

Most industrial and academic articles on the area of product development start by depicting the surrounding factors that form the reasons why studies have been conducted. Instead of contributing to these reproductions, a quotation from [2] is used:

> *Product development is an expression of the desire to survive as a company in the long term.*

The aim of most industrial companies is to stay digital in their product development effort as long as possible, that is to say to postpone the introduction of physical mock-ups to the later stages of development. In order to adopt such an approach, all departments involved must have the right preconditions for utilising the digital equivalence of the traditional physical mock-up [23] – the so-called Digital Mock-Ups (DMUs). The DMUs that will be elaborated on in this article are geometry-based and thus support different types of geometry application.

There are many examples of literature that describe the early stages of product development [15,19]. The tendency in many of them is to emphasise organisational aspects, analysis techniques, various technical concepts and requirement management. Naturally, these are important aspects to take into consideration but they generally appear not to take geometry aspects into consideration. The absence of a geometrical focus inevitably leads to inadequate descriptions of how product development ought to be conducted during the early stages, designated the preconceptual stages [10].

Design engineers are the primary type of geometry user that come to mind when describing the early stages of geometry application. This is a misconception concerning digital product development. The number of potential geometry users outside the traditional boundaries of geometry application in practise exceeds the number of design engineers that utilise computer aided design (CAD) applications. However, in order to support and improve the preconditions for geometry application in these early stages, there are areas of improvement that must be systematised.

In this publication, geometrical configuration is considered to be the primary enabler for broad organisational application of geometry. Products that are made from thousands of components, that incorporate complicated functional interdependencies and rich variance, are the reason for prescribing such a comprehensive approach. Furthermore, the geometrical configuration is vital in the prescribed framework but it must be accompanied by some equally important enablers. Geometrical configuration relies on the existence of configurable entities, so-called geometrical building blocks [12], that are unambiguously defined. Thus, the equally important enablers deal with methodology, processes and tools whose aim is to improve building block realisation and configuration.

The reason for this article is to enhance understanding of important areas that contribute to increased geometry application from the preconceptual stages of engineering design. The following chapter outlines the conducted research approach that forms a background to the thoughts presented. Chapters 3 to 5 describe the enabling preconditions from a process and methodology standpoint. A framework that builds on the presented theories has been, and is, under implementation in an industrial context. It is designated Automatic Vehicle Packaging (AVP), and it is briefly described in chapter 6. The final chapter contains a discussion on and conclusions from what has been presented and how it contributes towards reuse, modular design and global engineering design.

The underlying research work that has formed this publication was carried out within the product development unit of Volvo Truck Corporation, Göteborg, Sweden.

# 2 Research framework

The presented research framework builds on a research project that was initiated in autumn 1998. The initiation motive was based on the insufficient focus on geometry, both in academic and in industrial publications and literature. As stated in the introduction, digital product development relies on a sound and systematised way of managing geometry. Thus, the hypothesis is to define a Geometry Management Process (GMP) [11], see Figure 1, that should relate to existing academic literature in the area of product development. Furthermore, the GMP should complement industrial development processes by providing systematised tools, methods and guidelines that contribute to the elimination of rework. By adopting a holistic perspective to the application of geometry it is possible to eliminate rework not only in engineering design but also in what is traditionally referred to as downstream organisational functions.

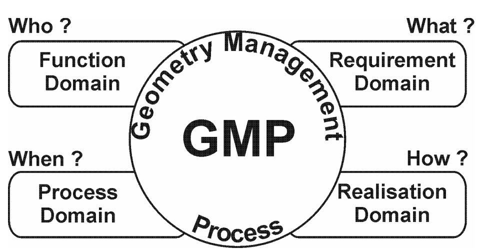


Figure 1. The Geometry Management Process.

During the establishment of the GMP, it became obvious that in order to eliminate rework by proposing working procedures that result in reuse, it was not sufficient to only focus on geometry. Another source of information must also be taken into account: non-geometric product information. In the research framework it is referred to as appurtenant product information. The collective term for geometry information and appurtenant product information is Geometry Based Product Information (GBPI), see Figure 2.

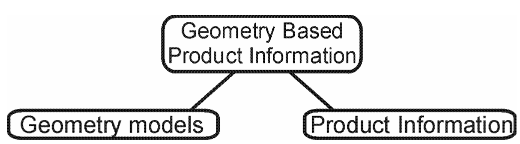


Figure 2. An overview of Geometry Based Product Information.

The GMP framework builds on several influencing areas that must be taken into account. These areas are dealt with by dividing the GMP into four different domains. The following areas have been considered as vital in the proposed GMP:

- Function domain. Organisational factors that deal with **who** the different geometry users are and the organisational function to which they belong.
- Requirement domain. Systematisation of **what** the geometry users' requirements are concerning GBPI.
- Process domain. GBPI evolves during the implementation of a product development project. Different GBPI requirements are met at different stages of development; the domain should answer to **when** the GBPI has reached a certain level of maturity.
- Realisation domain. Elimination of rework takes place by providing the geometry users with relevant GBPI. **How** should the relevant GBPI be realised?

Enabling preconditions for geometrical application in preconceptual stages of product development contribute to the presented research framework by:

- Outlining the theory of geometrical configuration and thereafter relating the presented theory to adequate references in the area of configuration.
- Proposing a process view of how to deal with geometrical building blocks in combination with traditional preconditions, that is existing support from legacy systems and company-specific development processes.
- Highlighting the possibilities that exist within the area of information integration; support for availability and accessibility of GBPI.

# 3 Geometrical configuration

Digital product development imposes changes on the traditional way of conducting product development. Some of these changes introduce opportunities worth exploring. Geometry-based Digital Mock-Ups represent one such opportunity. An example of a DMU is presented in Figure 3. The aim of the underlying research of this publication is to highlight enabling preconditions for taking advantage of DMUs from the preconceptual stages of engineering design, and thus configuration support. The significance of configuration support is that it should be possible to automatically create partial or complete DMUs.

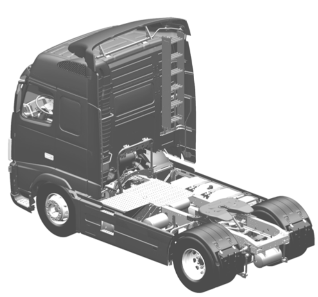

Figure 3. An automatically configured DMU.

Configuration management as described must have strategic business commitment to become a success. Business acceptance is crucial since the implication of configuration management is an extensive undertaking that must be made by the organisation. The main argument for selecting a geometrical configuration strategy is the possibility of obtaining support for managing very complex product variance. There are also other areas that must be addressed in order to setup a geometrical configuration framework. In the following sections, based on Figure 4, the core configuration framework areas are outlined.

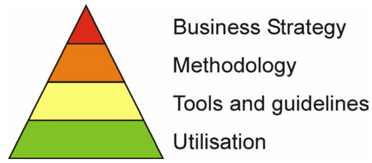


Figure 4. Established levels of configuration.

## 3.1 Business Strategy

A properly defined business strategy states the total customer offer. The customer offer can be transformed into a configuration space, that is to say the total number of feasible product combinations that is made available in the marketplace. In the engineering design area, the configuration space can be converted into the number of mock-ups that have to be followed up in a specific development project. As indicated in Figure 5, the term *number of mock-ups* incorporates both digital and physical mock-ups; it is important to emphasise this fact. Automatic geometrical configuration enables the number of DMUs to become much larger. At the same time, it makes it possible to support a much wider range of requirements on different types of configuration. This is especially true when comparing with manual configuration. However, the automatic configuration cannot entirely replace manual configuration because it requires that certain preconditions are fulfilled.

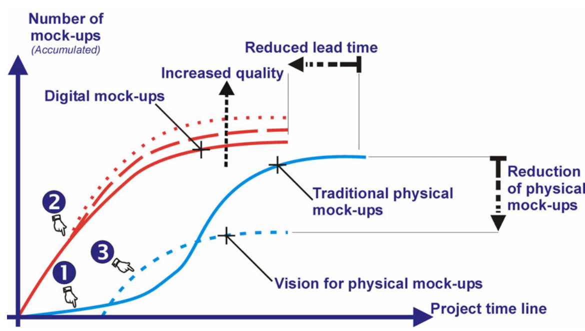


Figure 5. Strategic view of mock-ups [11].

The preconditions that must exist are composed of a combination of system, process and tool support.

## 3.2 Methodology

Geometry-based configuration management is not a topic that has received widespread scientific attention in the engineering design community. This methodology area builds on profound knowledge of GBPI, in other words in-depth knowledge of geometry modelling and information integration, that must be combined with process support. There are research efforts that have explored the configuration area, but not with the approach of the presented research framework. A few examples of related published research efforts are presented:

- Artificial Intelligence (AI) based systems for the support of configuration design and management [17].
- Generative modelling approach based on KBE, [14].
- State-of-the-practice in product configuration [28].
- Configuration management as a part of Systems Engineering processes [16].

The reason why geometrical configuration is an enabler for efficient engineering design work is elaborated on by utilising Figure 6.

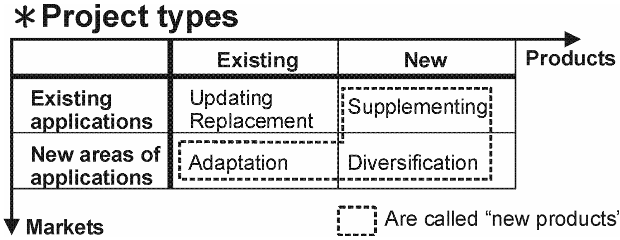


Figure 6. Design degrees of freedom [2].

Figure 6 is reproduced from [2] but almost the same type of view could have been obtained from [30]. The perspective of Figure 6 is sound since it invokes a customer-oriented view of ongoing engineering design development activities. There are, however, differences in how geometrical configuration applies to the different project types. This is due to the fact that geometrical configuration does not, as defined, involve any intelligence for the generation of new design solutions; it should cope with reproduction of the current level of maturity (LOM) of existing GBPI (the LOM concept is further outlined in chapter 4). Therefore, reuse of already created GBPI is one factor that renders the advocated approach efficient.

The following discussion is mainly based on Figures 5 and 6. The first quarter of Figure 6 is named *Updating Replacement*. This is a project type that relies on geometrical configuration that generates the product in production. Examples of benefits are product-unique GBPI for product specification, illustration and educational activities. Thus, the number of geometry users that can take advantage of the geometrical configuration is high. The next quarter of Figure 6, *Adaptation*, is typically an adaptation project where the existing product range is adapted for a new market or a new customer segment. The degree of carry-over (reuse), that is the GBPI from the already existing product range, is high. However, the adaptation will most likely introduce changes to the existing product documentation and perhaps also some redesign activities. The geometrical configuration contribution is the possibility of providing a relevant GBPI for design in context activities, but also for the product documentation activities that will follow. Quarter three of Figure 6, *Supplementing*, involves major changes to the product range that should support the existing customer offer. In the automotive industry, and in the truck industry in particular, replacement of the existing product range seldom means starting off from scratch. The associated risks and costs with starting off from scratch imply that a carry-over scenario normally takes place. The business strategy is to have a certain carry-over percentage. From a geometrical configuration point of view, one result of the carry-over percentage is that already from the earliest stages, there are geometric entities that populate a certain percentage of the intended configuration space. The consequence of carry-over for digital mock-ups can be seen in Figure 5, the numbers of DMUs in early stages increase very rapidly. The carry-over process itself is an interesting phenomena; it is acknowledged in scientific literature but only sparsely described. Geometrical configuration constitutes an enabling opportunity since it makes it possible to pinpoint certain reference products from the product range that can be investigated for carry-over. The final quarter, and project type, is *Diversification*. It is not considered to be a product development project with the traditional boundaries. [14] argues about the necessity to put these types of innovative projects into R&D activities. Thus, the preconditions for supporting this product type with the advocated geometrical configuration are rather limited, partially due to the lack of predefined product documentation that can be reused.

Hitherto in this methodology section, process and project aspects have been covered, i.e. how geometrical configuration can act as an enabler in different types of development project. The advocated geometrical configuration methodology builds on a defined configuration procedure that is depicted in Figure 7.

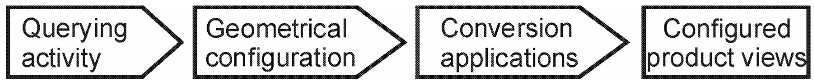


Figure 7. The configuration procedure [13].

In order for the geometrical configuration to work as an enabler in digital product development, the configuration procedure must be applied. In earlier publications, such as [12] and [13], key methodology elements of the configuration procedure have been more thoroughly outlined. Examples of these methodology elements are geometrical positioning principles, geometrical building blocks (BBs) and configurable product views. In the remainder of this publication, further enabling methodologies (preconditions) will be discussed. Chapters four and five contain enabling preconditions for working with geometrical configuration in an engineering design context from preconceptual stages. Chapter 4 deals with a prescriptive process for BB management. This is a delicate issue to master, partly due to the fact that many mature industries utilise legacy systems and established product development processes. Chapter 5 addresses the querying activity of Figure 7. It is based on the fact that most companies are facing a heterogeneous information environment and the configuration procedure utilises various types of configuration information with different origin.

## 3.3 Tools and guidelines

The engineering design environment has undergone considerable change during the past decade or two due to computerisation. If the perspective is extended some further decades, we see that many larger firms developed their own geometric modelling tools. Nowadays, geometric modelling tools, in other words CAD applications, have matured and are to be considered as off-the-shelf solutions. At the same time it must be acknowledged that CAD systems are very complex tools and the 'off-the-shelf' expression is actually sometimes misused.

CAD applications have more or less been the single source of geometry representation. During the past decade, CAD applications have been supplemented with so-called visualisation applications. The number of different visualisation applications and the fields of utilisation have literally exploded in recent years. The geometry models in the visualisation applications are generally much smaller in size compared with the original native geometry models (~ 80-95 % reduction). The reduction takes place in the conversion process from native formats to visualisation formats (the conversion applications in Figure 7). The consequence is that design history and construction geometry, for example, are removed from the native formats and accordingly the visualisation formats consist of geometry models that represent the status of the native format upon conversion. From a business standpoint, it is extremely important to support these visualisation applications in a systematic way in order to promote geometry application. This is particularly important if there are only DMUs during the preconceptual and conceptual stages of engineering design; the visualisation applications are a necessity for all geometry users not utilising CAD applications. Furthermore, larger companies often utilise more than one CAD application in their organisations. The visualisation applications can serve as a bridging environment in such multiCAD environments.

For companies working in a global engineering design environment with design offices located on many continents, geometry sharing is crucial to business. Most CAD systems have an underlying database system that manages the CAD geometries. A few of the visualisation applications have database systems of their own that manage conversions, version control and updates. In order to work globally, there is a need for a structured approach to managing these databases. The same type of structuring must be made for the legacy information systems. Examples of issues that are important are information infrastructure, time zones and replication techniques.

The tools are not adequate for making the organisation work in a concurrent, efficient manner. Guidelines that orientate the personnel often seem to be lacking in scientific literature [3]. The implementation of tools comes off badly if there are no thorough and clear, unambiguous guidelines. The guidelines serve many objectives, a few examples are presented:

- Applicability context
- Setting the terminology
- Presenting the methodology

## 3.4 Utilisation

Theories, methodologies and guidelines are worthless if they cannot be interpreted and put into practice. The same conditions apply to the presented geometrical configuration. AS-IS development preconditions are often encumbered with a historical heritage, and this heritage must be understood and accounted for. Another challenge concerns the TO-BE scenario; it is by no means static. The TO-BE scenario is influenced by continuous improvements in areas such as tools, information architecture and information technology. Furthermore, the inertia of change is severe in many larger companies, and a crucial question is how to tackle issues of change without jeopardising the ongoing business. The inertia of change is partly made up of all the product documentation that has already been produced.

It is generally accepted that in order to be capable of proposing change and identifying shortcomings, a knowledge base must be created that is formed from thorough understanding of the AS-IS situation, together with an in-depth knowledge of the product. Therefore, the best way of detecting shortcomings and formulating new theories and methodologies is to integrate process development and methodology development into the development organisation where the actual utilisation takes place. The same thoughts are very much applicable to design research. One of the disadvantages of such research philosophy is that it may be more time consuming.

*Reflection*

In order to support increased geometry application from the preconceptual stages, all the previously prescribed established levels of configuration are enabling preconditions. There is always room for improvement and the improvement potential is detected by working in the AS-IS environment together with the personnel who make the development effort sustainable. The presented enablers can therefore be even better at enabling.

# 4 BB at the fuzzy front end

Geometrical configuration builds on an advocated approach where geometric building blocks act as a precondition; they are the entities to configure. Therefore it is necessary to establish how to work with these BBs already from preconceptual stages.

There are various requirements and conditions that must be dealt with in order to support the concept of BBs. The adapted perspective of BBs utilises a concept that was presented in [10]; the evolution of geometric maturity. The prescribed evolution concept builds on a top-down approach where the Level Of Detail (LOD) is central. In order to apply the evolution concept and implement it in a global engineering design environment, further detailing is required where the following areas are taken into account:

- The defined generic product development process
- Correlation to the AS-IS IT infrastructure
- Carry-over aspects
- Amount of product documentation

In accordance with Figure 6, the scope of most development projects differs. Therefore, the prerequisites also change depending on the scope and ambitions of each project. The solution to these different types of project scenario is to prescribe a generic product development process, a process template, which is utilised in setting up new projects, see Figure 8. [2] referred to this type of generic disposition as a common procedure.

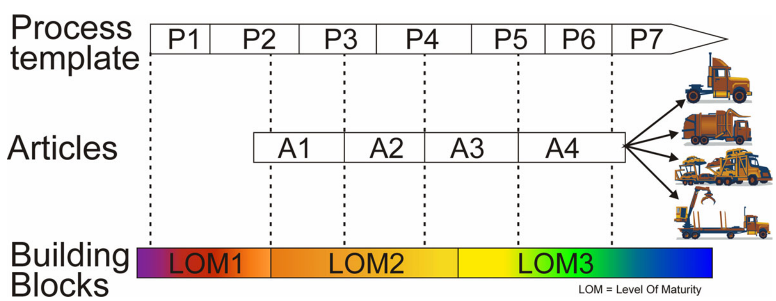


Figure 8. Correlation map of processes.

The legacy information architecture [23] is the backbone of many larger companies. Thus, large investments have already been made in legacy systems that are up and running and supporting the global engineering design environment as well as downstream systems. One can not bypass or replace this information architecture in a single move; that would jeopardise the entire production environment [6]. Instead, complements and a gradual refinement are the advocated way of improving the infrastructure situation. In Figure 8, the existing legacy system support is illustrated by the article process. The article process is the supported release procedure for articles, an established process that is working properly.

An obvious failing is detectable when comparing the process template and the article process of Figure 8. Thus, the support for preconceptual stages in digital product development is lacking. The proposal is to incorporate an additional BB release procedure. The motive for such an extra process is the possibility of taking advantage of the established process template and article process and complementing them with a BB release procedure whose primary objectives are to support aspects of preconceptual working procedures, carry-over and geometrical configuration. It must be acknowledged that this additional release process will inevitably entail an extra product documentation burden, i.e. compared to the present way of working, and the ambition must be to keep this burden to a minimum.

Through the introduction of the BB release procedure, the existing process support and system support will also be capable of supporting:

1. Envelopes and space allocation issues in preconceptual stages
2. Follow-up of rough design entities

There are two major advantages of introducing this additional BB release procedure:

1. It is possible, through modest means, to incorporate it into the existing system support of the legacy information architecture.
2. It supports all the different project types that have been described. Accordingly, it constitutes an instrument for correlation with the existing process and system support.

The BB release procedure builds on three LOMs. This is a compromise where high priority has been given to reducing the documentation burden of the design engineers. The LOM concept builds on the break-down of the BBs in accordance with the GBPI concept, see Figure 9.

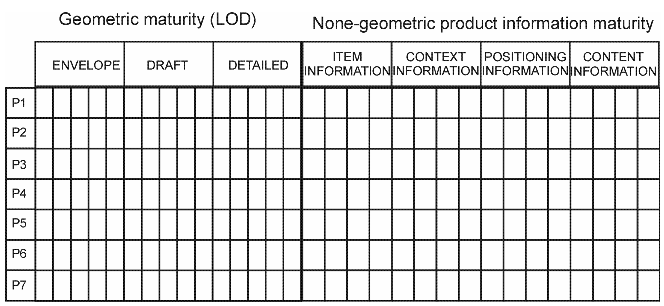


Figure 9. The LOM matrix.

Two orthogonal dimensions form the LOM matrix; maturity of GBPI and the process coordination of the GBPI. The geometric maturity (LOD) concept classifies the geometry content of the BB [8], while the other concept deals with the maturity of non-geometric product information. Both the horizontal and vertical axes are further broken down. The principle is presented and further details of the different concepts would be too extensive. The flexibility of the LOM matrix ensures that it supports all the different project types and their various carry-over scenarios.

# 5 Information integration

In order to support geometrical configuration, many different types of information must be accessed, stored and analysed. The collective name of this heterogonous amount of data is Configuration Information. The presented concept builds on fundamental techniques from the field of information integration and data warehousing, see Figure 10 [9,29].

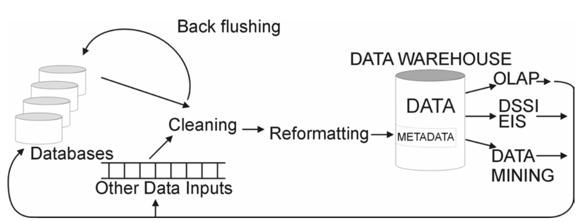


Figure 10. Principles of data warehousing [29].

In many larger companies the backbone of the information system is based on legacy information architecture. The legacy structure does not have the ability to support all the information requirements and applications with relevant product and process data. Thus, apart from the legacy information architecture, there are vast numbers of proprietary information sources throughout the company [23], see figure 11. The consequence is that the product development environment is extremely heterogeneous and the configuration information is widely dispersed.

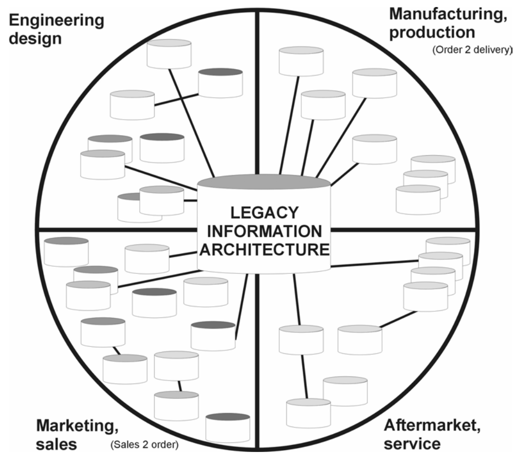


Figure 11. Potential sources of configuration information.

Information integration is considered to be an enabling precondition. There are many reasons why this is the case. Some of them will be elaborated on in the following section.

The legacy architecture has many advantages. For example: (1) it is a mature and established IT solution, (2) which has been formalised and fully implemented into the engineering design environment. (3) Guidelines and educational material exist to instruct the end-users, who are spread throughout the organisation. There are, however, downsides to this architecture. These downsides are to be considered as opportunities for improvement.

Engineering design activities are to a certain extent characterised by innovation and therefore demand flexibility in the supporting systems. Such flexibility can be hard to ensure with the formalisation that encompasses the legacy systems. An information integration approach can bridge this gap in flexibility by offering interim solutions. However, there must be a common understanding regarding these interim solutions – when, and if, they evolve and eventually become rather stable and worth formalising, they should, if feasible, be incorporated into the legacy architecture.

Three examples are given of occasions when an information integration approach complements the existing architecture with important functionality:

- Certain types of search criterion require restructuring of the original legacy data in order to support acceptable query performance and functionality.
- Other types of search criterion build on combinations of data that are not feasible within the legacy architecture.
- There exists information that must be stored and systematised where there is no support from either the legacy systems or the proprietary systems. The information integration approach is in such cases an enabler for systematised storage and therefore provides availability, accessibility and trustworthiness [4].

## 5.1 Configuration information

Configuration information is a comprehensive collection of different types of product information and process information that must support geometrical configuration. This subsection will provide three somewhat more modulated perspectives on relevant configuration information.

**BB information.** The building blocks will evolve in the development effort and accordingly the BBs will change when updates are made to them. The building blocks are documented both in the legacy information system and in the CAD systems. The query activity of the configuration procedure deals with searchability criteria for these BBs. Accessibility and availability of meta-data from the legacy systems as well as the meta-data from the CAD database systems is therefore essential in order to provide the right preconditions for querying this type of configuration information.

**Structure information.** Configuration information embraces many different views of the product. These views are often based on different types of product structure or process structure [13], such as modular product structures or manufacturing process structures. It is particularly important to emphasise the aspects of structures since product configuration deals with both fixed product structures and potential structures of the configurable products [1].

**Product specifications.** In order to be able to geometrically configure a DMU, product specifications are needed. These specifications can be collected from sources such as the marketing/sales area, or from databases that manage prototype specifications. They are therefore needed to describe the configuration context. Thus, product specifications are regarded as configuration information.

## 5.2 Knowledge management

The presented information integration and geometrical configuration approach bear a strong resemblance to thoughts and theories presented within the area of knowledge management. Product knowledge embraces the entire product life-cycle and thus too multiple product cycles. In order to make product knowledge from an individual available to other personnel, product documentation must take place; [27] have a point in their statement: “product documentation is painful”. It is reasonable to also take into consideration who will actually perform the required documentation. This is largely a task that is imposed on the design engineer. Thus, by requiring further product documentation, even less time is spent on the actual engineering task. From a GMP perspective, the following scenario is illustrated, see Figure 12, and it is a perception that has evolved during the course of the research. A contradiction will appear, one that is due to the most critical performance criteria in industry: cost.

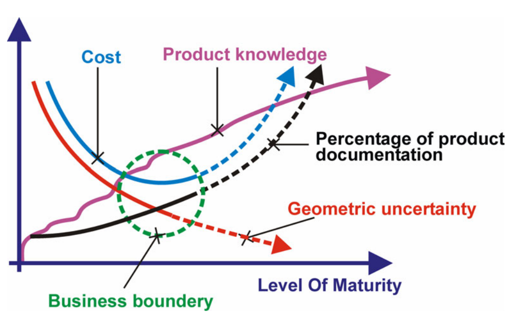


Figure 12. A reflection on product documentation.

The contradiction mentioned must be addressed in a manner that makes it worth investing additional resources on extending the amount of product documentation. Another aspect that also must be investigated concerns the way the information is structured and systematised.

The scientific community has elaborated on some issues that touch upon this contradiction. A few examples are shown. (1) An issue that is being discussed concerns how much time the engineering designers spend on managing information in their daily work. [4] refers to additional authors who deal with this issue of managing information. The estimates presented relate to just about 25% of each designer's working day. (2) The possibility of generating design information for use in downstream applications or in the later stages of the product life-cycle is debated [26]. (3) The issue is one of systematising design knowledge by first abstracting it and then generalising it into a reusable form [18]. Data mining technology is an good example of how knowledge discovery can be brought into the design environment to support reuse by utilising existing design repositories [7].

There are many acronyms associated with different types of knowledge capitalisation and knowledge deployment activity. Product Data Management (PDM) [24], Product Life-Cycle Management [5], Knowledge Based Engineering (KBE) [14,22], Knowledge Based Systems (KBS) [25] – all are examples of scientific efforts, some with industrial involvement, that one way or another touch on the area of knowledge management and ways of systematising engineering design knowledge.

# 6 Automatic Vehicle Packaging

"By automatic design we mean design procedures which are capable of being completely specified in a form which a computer can execute without human intervention" [21]. The derived benefit from the AVP framework is the potential for automatically providing relevant and accessible DMUs to a rich variety of geometry users throughout the extended enterprise by utilising the geometrical configuration procedure,.

The concept of AVP has emerged to answer to the original GMP research question. AVP belongs to the Realisation Domain of the GMP and should answer **how** relevant GBPI should be made available to a wide variety of geometry users throughout the extended enterprise. Research findings from the other domains, and the GBPI concept, have served as input for the AVP framework [8,10,11,12,13].

The framework has evolved gradually over the past five years and is currently industrially implemented and utilised. There are still requirements that until this publication not have been resolved, but continuous progress is being made to meet these requirements too.

Some limitations have been imposed in the configuration procedure. They primarily concern colours, textures and textiles. The reason for not taking these examples into the configuration procedure is that they do not introduce any changes in the geometrical space allocation of the DMUs. Therefore they are not in this context considered to contribute towards an increase in the configuration space.

One of the key elements of the presented information integration approach is the potential elimination of data redundancy by providing a so-called Engineering DataBase. Another important aspect of the AVP framework is that it has the potential to remove repetitive manual tasks and instead let engineers and other geometry users focus on other things. Other research initiatives have also acknowledged such potential within engineering information systems [20]. Some of the KBE initiatives have argued about similar benefits, they refer to the potential to automate mundane time-demanding tasks [e.g. 22].

Some of the cornerstones and key features that constitute the AVP framework are presented below:

- MultiCAD capabilities
- Support for multiple visualisation applications
- A structured and systematised environment for querying of appurtenant product information
- Product structuring support
- Performance
- Scalability

One of the challenges of the AVP concept has been its application in preconceptual stages of engineering design. [14,15,17] conclude that "new product development" really deals with reuse of a large portion of the already reprocessed product knowledge and its adaptation to the new conditions. This collective conclusion definitely applies to the truck industry. The enabling preconditions that must be dealt with in order to make the AVP work from these stages is the prescribed BB release procedure, with its LOM matrix, and the information integration approach.

# 7 Conclusions

Engineering design in the global economy is affected by the continuous change that occurs in society. The truck industry serves as an example. Four decades ago, the total number of European truck manufacturers was 45. Since then, mergers and hostile take-overs have reduced the number of independent truck manufacturers to 6. These major players are more or less globally committed, which in turn has an impact on how the engineering design area must be managed. The consequence on the products is that they must be adaptable to local market conditions. The different conditions have their origin in legalisation, transport missions, vehicle utilisation, operating environments, discrepancies and so on. This will inevitably lead to product adaptability requirements, which in turn will eventually result in increased product variance.

The computerisation of the engineering design environment, and especially the application of DMUs, acts as an enabler for global engineering design. Communication of design solutions and design concepts between different engineering design sites is today possible in a manner that would have been impossible just 5 years ago. At the same time, the product variance that global engineering design teams must manage is increasing due to the previously mentioned product adaptation; i.e. the configuration space becomes even larger. It is for this reason that management of systematised approaches to information integration and geometric product configuration is regarded as crucial to the business areas in order to obtain a competitive advantage in the global economy.

Geometrical building blocks are preconditions for the advocated configuration procedure, that is to say since they are the smallest configurable entities. The presented configuration deals with ways of making product variance manageable from a DMU perspective. Product variance is a concept that can be dealt with by adopting a modular approach. Thus, theories of modularisation are utilised to create adequate geometrical building blocks. This is a pertinent approach since the BBs are utilised in all relevant product configuration and the outcome is an advocated approach which relies on the reuse of BBs, which in turn leads to the elimination of rework.

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